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May 1996 SWAC trial, Kyparissiakos Gulf

8.1. Description of the SWAC Acoustic Source and May 1996 Trial

Figure 8.1.1 describes the active acoustic source characteristics (Annex E). During the 4 day trial period, three runs were completed each day (Fig. 2.1). The duration of each run was approximately 3 h with 4 s of acoustic energy transmitted at the beginning of every minute. The waveforms described in Fig. 8.1.2 show the concurrent low and mid frequency transmissions. Throughout the trial, the average source depth was 75m (85 m during run 9). Detailed run summaries for the trial are contained in Annex F.

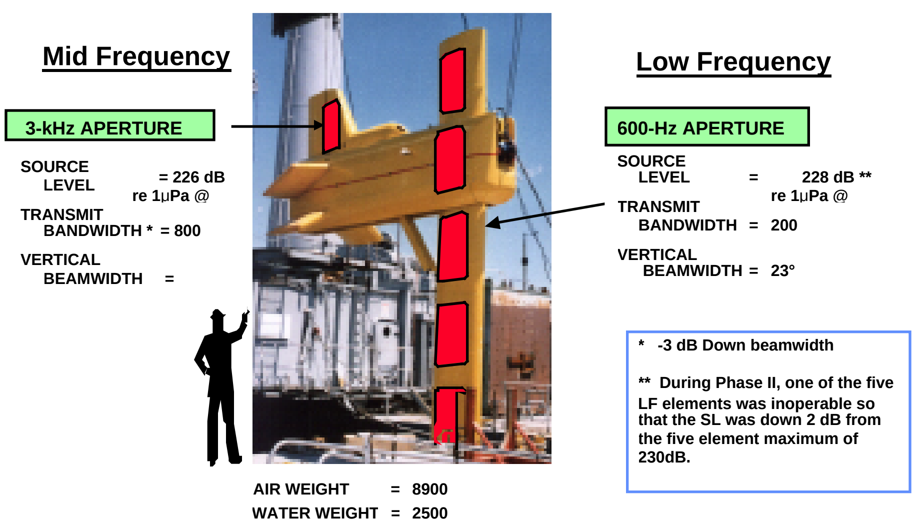

Figure 8.1.1. *Towed Vertically Directive Source characteristics*

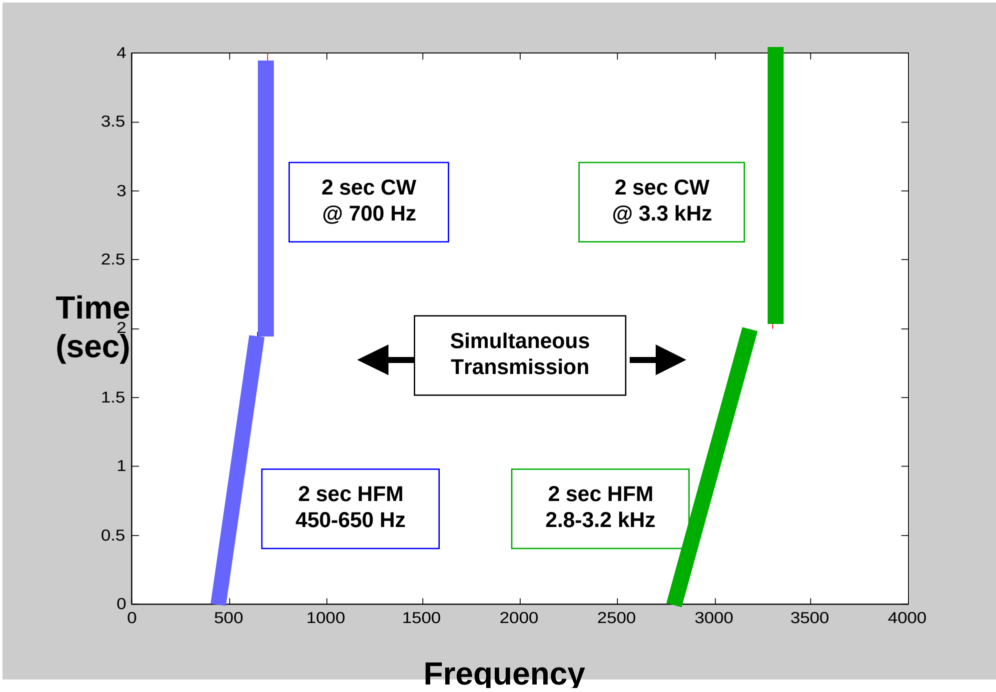

Figure 8.1.2 *Four-second acoustic transmissions during the trial*

8.2 Prediction of Propagation Characteristics in the Kyparissiakos Gulf (Information supplied by P. Nielsen, SACLANTCEN).

8.2.1 Introduction

The Environmental Modelling Group at SACLANTCEN has done a prediction of sound propagation in the Kyparissiakos Gulf. The aim of the analysis was to achieve a general picture of the sound propagation conditions during the SWAC experiment in the time period 12-13 May, 1996. A range-dependent raytrace model was applied, and the results are given as received pressure levels in dB re 1 μPa as a function of range and azimuth for fixed source-receiver combinations. A selection of 2 frequencies, 3 geographical source positions and 3 receiver depths are considered in the analysis.

8.2.2 Propagation modelling

A full range-dependent, two-dimensional raytrace model was used for calculating the received pressure levels as function of frequency, range and depth. The environmental input parameters for the model, such as bathymetry, sound speed profiles and geo-acoustic properties of the bottom, can vary both in range and depth, see Fig. 8.2.1. The output levels from the raytrace model has been compared with results obtained from alternative propagation models for the same environment. An excellent agreement between the models was seen. Therefore, accurate propagation calculations can be done by using this model including measured details in the environment affecting the propagation characteristics. The prediction has an estimated accuracy of ±3 dB.

The calculation of the sound propagation in the Kyparissiakos Gulf has been performed for 3 selected geographical positions of the source on the tracks considered during the SWAC experiment in 1996. Position A on track A-B, position C in the middle of track A-B and position E on track E-F were selected to present the *general* propagation conditions in the area, see Fig. 8.2.2.

Fixed source depths of 76 m and 85 m were used, which correspond to the tow depths of the SWAC source. This is also the depth of the sound channel resulting in optimum propagation conditions, see Fig. 8.2.2. The received levels are established assuming that continuous waves were transmitted by the source at a frequency of 600 and 3000 Hz. These frequencies are close to the centre frequencies of the broad-band transmissions during the experiment, and also correspond to maximum source levels. The frequency-dependent vertical and horizontal directionality of the source have been included in the computations. The vertical beam pattern was modelled by including rays with maximum propagation angles of ±12.5° for 600 Hz and ±10° for 3000 Hz with respect to horizontal without shading of the intensity.

Three receiver depths of 20, 85 and 600 m were selected, and a maximum range from the source of ~50 km was chosen. The received levels given at a horizontal slice at the receiver locations were established by analyzing the sound propagation along 36 radials in azimuth with the source as the centre, (Figs. 8.2.2-8.2.4). The levels along each radial were combined in azimuth by interpolation.

The ambient noise levels for the Kyparissiakos Gulf is also presented for comparison with the received levels. The noise levels were acquired during Rapid Response '97 exercise in September 1997, and the data are shown as spectrum levels and ambient noise roses, see Fig. 8.2.5 and 8.2.6. The observed ships during the Rapid Response '97 are shown together with the ambient noise roses. The ship density from historical databases has been extracted and compared for May and September. No significant changes in density was seen for those two months. Therefore, it is assumed that the acquired ambient noise levels during Rapid Response '97 represent the levels for the SWAC experiment in May 1996.

It was concluded from the Rapid Response '97 that two main shipping lanes exist in the area of the Kyparissiakos Gulf. One shipping lane goes along the Greek coast in the Northwest-Southeast direction towards the Adriatic Sea, and the second shipping lane in the East-West direction from the Black Sea to the Western Mediterranean (Figs. 8.2.5 and 8.2.6).

8.2.3 Environment

The environmental input parameters for the propagation model are based both on measured parameters during the experiment and database parameters extracted from the AESS (Allied Environmental Support System).

The sound speed profiles used in the calculations were derived from temperature profiles measured on the same day as the experiment. Only three temperature profiles were acquired along each track, but the profiles are very similar and no significant changes in received levels are seen from the modelling when all or just one profile is used. Only one profile is used in the results presented here, where the chosen profile is these one acquired nearest to the geographical source position considered.

The bathymetry along each of the 36 radials for the 3 geographical locations of the source were extracted from the AESS database system, which has a 0.1 minute resolution. All the extracted bathymetry features were included in the modelling.

The bottom parameters along the radials were extracted from the BLUG (Bottom Loss UpGrade) database. The data were converted to a geo-acoustic model and used as input to the SAFARI model to generate reflection loss tables as a function of grazing angle for use in the raytrace model. Any range-dependent properties of the bottom parameters were also included in the calculations of the received levels.

The sensitivity of predicted levels to changing bottom parameters was considered too. A bottom with a higher sound speed (higher critical angle) than the BLUG bottom was tried. However, no significant changes were seen in the received levels.

8.2.4 Results

Considering all combinations of source-receiver positions and frequencies it was found that the geographical location of the source has little influence on the *general* propagation characteristics in the area. There are, of course, changes in details caused by slightly different sound speed profiles and bathymetry depending on the site considered. Therefore, the general conclusions on the propagation characteristics in the area can be drawn based on the received levels for one of the sites.

Changes in the sound levels as a function of receiver depth for a given geographical source location are almost the same for the two frequencies. Therefore, the depth dependence of the received levels can be assessed by only considering one of the frequencies. The results for the 600 Hz transmission at site A is used as an example. It is seen in Fig. 8.2.2 and 8.2.3 that the received levels are higher for the receiver located at a depth of 85 m compared to the other two receiver depths. At the shallow receiver (20 m) convergence zones with high levels can be seen at a range of ~25 km and ~40 km as indicated by the raytrace, see Fig. 8.2.1. The level at maximum range of 50 km is around 140-150 dB re 1 μPa.

The propagation conditions in the sound channel are excellent as seen in Fig. 8.2.2 (85 m depth). Here levels between 150-160 dB re 1 μPa are seen out to 50 km in range, and this level interval covers approximately 60 % of the total area considered in the propagation.

The levels at the deep receiver (600 m) are similar to the shallow receiver (20 m) as seen in Fig. 8.2.3, but the area insonified is less than for the shallow receiver due to changes in bathymetry and the propagation conditions. In general there is a moderate depth dependence in the received levels, which is a 10 dB higher levels for receivers in the sound channel compared to the other depths considered.

The frequency dependence of propagation is illustrated in Fig. 8.2.4 for a receiver depth of 85 m. The effect of the horizontal beam pattern is clearly seen for 3000 Hz, where the maximum transmitted levels are in the direction perpendicular to the tow direction of the source (from A towards B). For 600 Hz transmission the source has little horizontal directionality. Sound levels are considerably higher at 600 Hz than at 3000 Hz. There is up to 20 dB difference in levels between the two frequencies (intensity ratio equal 100), where the decrease in levels for the high frequency transmission is caused by source directivity effects, increased volume attenuation (8.2 dB/50 km higher at 3000 Hz) and changes in propagation characteristics.

8.2.5 Summary

The numerical analysis of the sound propagation in the Kyparissiakos Gulf for 3 geographical positions of the source, 3 receiver depths and 2 frequencies show little effect of the position of the source on the received levels.

Generally, the received levels are found to be moderately dependent on the receiver depth with a 10 dB higher (10 times higher intensity) received levels in the sound channel compared to the other receiver depths considered.

The received levels show very strong dependency on the frequency in *general*, with 20 dB higher levels (100 time higher intensity) predicted for 600 Hz compared to 3000 Hz transmission. This is mainly caused by horizontal beam pattern, volume attenuation and changes in propagation conditions at different frequencies.

The maximum levels at 50 km are received in the sound channel at a frequency of 600 Hz with levels ranging between 150 and 160 dB re 1 μPa. This level interval covers approximately 60 % of the total area considered in the propagation.

The ambient noise level in the Kyparissiakos Gulf during the SWAC experiment in May 1996 is based on measurements done during the Rapid Response exercise in May 1997. The maximum ambient noise level was around 92 dB re 1 μPa/√Hz at 40 Hz (2 minute averaging, 1/3-octave band averaging and a receiver depth of 27 m), and ~65 and 50 dB re 1 μPa/√Hz at 600 and 3000 Hz, respectively. Therefore, the ambient noise levels are much lower than the levels predicted from the SACLANTCEN source at the maximum range of 50 km.

Annex G shows results of NUWC independent analyses.